



Designation: D1687 – 17

Standard Test Methods for Chromium in Water¹

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This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 These test methods cover the determination of hexavalent and total chromium in water. Section 34 on Quality Control pertains to these test methods. Three test methods are included as follows:

Test Method	Concentration Range	Sections
A—Photometric Diphenyl-carbohydrazide	0.01 to 0.5 mg/L	7 – 15
B—Atomic Absorption, Direct	0.1 to 10 mg/L	16 – 24
C—Atomic Absorption, Graphite Furnace	5 to 100 μ g/L	25 – 33

1.2 Test Method A is a photometric method that measures dissolved hexavalent chromium only. Hexavalent chromium can also be determined by ion chromatography, see Test Method D5257. Test Methods B and C are atomic absorption methods that are generally applicable to the determination of dissolved or total recoverable chromium in water without regard to valence state. ICP-MS or ICP-AES may also be appropriate but at a higher instrument cost. See Test Methods D5673 and D1976.

1.3 Test Method A has been used successfully with reagent grade water Types I, II, and III, tap water, 10 % NaCl solution, treated water from a synthetic organic industrial plant that meets National Pollution Discharge Elimination System (NPDES) permit requirements, and EPA-extraction procedure leachate water, process water, lake water, effluent treatment, that is, lime neutralization and precipitation of spent pickle liquor and associated rinse water from stainless steel pickling. Test Method C has been used successfully with reagent water, stock scrubber water, lake water, filtered tap water, river water, well water, production plant water, and a condensate from a medium BTU coal gasification process. Matrices used, except for reagent water, are not available for Test Method B. It is the user's responsibility to ensure the validity of these test methods for waters of untested matrices.

¹ These test methods are under the jurisdiction of ASTM Committee D19 on Water and are the direct responsibility of Subcommittee D19.05 on Inorganic Constituents in Water.

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1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversion to inch-pound units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see 4.2, 20.3, and 20.8.1.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

- D858 Test Methods for Manganese in Water
- D1066 Practice for Sampling Steam
- D1068 Test Methods for Iron in Water
- D1129 Terminology Relating to Water
- D1193 Specification for Reagent Water
- D1688 Test Methods for Copper in Water
- D1691 Test Methods for Zinc in Water
- D1886 Test Methods for Nickel in Water
- D1976 Test Method for Elements in Water by Inductively-Coupled Argon Plasma Atomic Emission Spectroscopy
- D2777 Practice for Determination of Precision and Bias of Applicable Test Methods of Committee D19 on Water
- D3370 Practices for Sampling Water from Closed Conduits
- D3557 Test Methods for Cadmium in Water
- D3558 Test Methods for Cobalt in Water
- D3559 Test Methods for Lead in Water
- D3919 Practice for Measuring Trace Elements in Water by Graphite Furnace Atomic Absorption Spectrophotometry

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard

[D4691 Practice for Measuring Elements in Water by Flame Atomic Absorption Spectrophotometry](#)
[D4841 Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents](#)
[D5257 Test Method for Dissolved Hexavalent Chromium in Water by Ion Chromatography](#)
[D5673 Test Method for Elements in Water by Inductively Coupled Plasma—Mass Spectrometry](#)
[D5810 Guide for Spiking into Aqueous Samples](#)
[D5847 Practice for Writing Quality Control Specifications for Standard Test Methods for Water Analysis](#)
[E60 Practice for Analysis of Metals, Ores, and Related Materials by Spectrophotometry](#)
[E275 Practice for Describing and Measuring Performance of Ultraviolet and Visible Spectrophotometers](#)

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms used in this standard, refer to Terminology [D1129](#).

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *continuing calibration blank, n*—a solution containing no analytes (of interest) which is used to verify blank response and freedom from carryover.

3.2.2 *continuing calibration verification, n*—a solution (or set of solutions) of known concentration used to verify freedom from excessive instrumental drift; the concentration is to cover the range of calibration curve.

3.2.3 *laboratory control sample, n*—a solution with the certified concentration(s) of the analytes.

3.2.4 *total recoverable chromium, n*—a descriptive term relating to the forms of chromium recovered in the acid-digestion procedure specified in this test standard.

4. Significance and Use

4.1 Hexavalent chromium salts are used extensively in metal finishing and plating applications, in anodizing aluminum, and in the manufacture of paints, dyes, explosives, and ceramics. Trivalent chromium salts are used as mordants in textile dyeing, in the ceramic and glass industry, in the leather industry as a tanning agent, and in photography. Chromium may be present in wastewater from these industries and may also be discharged from chromate-treated cooling waters.

4.2 The hexavalent state of chromium is toxic to humans, animals, and aquatic life. It can produce lung tumors when inhaled and readily induces skin sensitization.

5. Purity of Reagents

5.1 Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical

Reagents of the American Chemical Society³ where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Specification [D1193](#), Type I, II, or III water. Type I is preferred and more commonly used. Type II water was specified at the time of round robin testing of these test methods.

NOTE 1—The user must ensure the type of reagent water chosen is sufficiently free of interferences. The water should be analyzed using the test method.

6. Sampling

6.1 Collect the sample in accordance with the applicable ASTM standard as follows: Practice [D1066](#), or Practices [D3370](#). The holding time for the samples may be calculated in accordance with Practice [D4841](#).

6.2 Samples to be analyzed by Test Method A should be stabilized upon collection by addition of sodium hydroxide solution to a pH greater than or equal to 8, or analyzed immediately. Minor delays in stabilization or analyses of samples containing sulfur reduction compounds can produce significant loss in hexavalent chromium. Acidic samples containing hypobromite, persulfate, or chlorine could oxidize trivalent chromium, if present, to hexavalent form upon preservation, resulting in a positive interference. When the presence of these oxidizing compounds is suspected, samples should not be preserved but analyzed immediately. It will be evident that in this case, the simultaneous presence of reducing compounds could not be anticipated.

6.3 Samples to be analyzed by Test Methods B and C shall be preserved by addition of HNO₃ (sp gr 1.42) to pH of 2 or less immediately at the time of collection, normally about 2 mL HNO₃/L. If only dissolved chromium is to be determined, the sample shall be filtered through a 0.45-μm membrane filter ([11.8](#)) before acidification.

NOTE 2—Alternatively, the pH may be adjusted in the laboratory within 14 days of collection. However, acid must be added at least 24 hours before analysis to dissolve any metals that adsorb to the container walls. This could reduce hazards of working with acids in the field when appropriate

³ *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

TEST METHOD A—PHOTOMETRIC DIPHENYLCARBOHYDRAZIDE

7. Scope

7.1 This test method covers the determination of dissolved hexavalent chromium in water.

7.2 The test method is applicable in the range from 0.01 to 0.5 mg/L chromium. The range may be extended by appropriate sample dilution.

7.3 This test method has been used successfully with reagent grade water Types I, II, and III, tap water, 10 % NaCl solution, treated water from a synthetic organic industrial plant that meets NPDES permit requirements, EPA-extraction procedure leachate water, process water, lake water, effluent from treatment that is, lime neutralization and precipitation of spent pickle liquor and associated rinse water from stainless steel pickling. It is the responsibility of the user to ensure the validity of the test method to waters of untested matrices.

8. Summary of Test Method

8.1 Hexavalent chromium reacts with 1,5-diphenylcarbohydrazide (s-diphenylcarbazide) in an acid medium to produce a reddish-purple color. The intensity of the color formed is proportional to the hexavalent chromium concentration.

9. Interferences

9.1 Vanadium, titanium, or iron present at concentrations of 5 mg/L yield a 10 to 30 % reduction in recovery of chromium. Copper at 100 mg/L yields a 20 to 30 % reduction in recovery in the presence of sulfate. Mercury gives a blue-purple color, but the reaction is not very sensitive at the pH employed for the test.

9.2 Nitrite concentrations in excess of 10 mg/L as NO_2 yield low test results. Sulfamic acid may be added (~ 10.1 g) prior to the addition of diphenylcarbazide solution to minimize nitrite interference. Add sulfamic acid only when the presence of nitrite has been positively established. Excess sulfamic acid itself creates a slightly positive interference.

9.3 Sulfide and sulfite reduce chromate in an acid medium to give low results.

9.4 Several sample matrices have been identified which produce a yellow-orange complex that interferes with this quantification. When this occurs, it may be remedied by inverting the indicator-buffer sequence. In these cases the analyst should evaluate the matrix effect with the additions of spikes (Guide D5810).

9.5 Although each interferent has been reported, most of the common interferences are eliminated by the preservation procedure at the time of collection. The potentially interfering metals are precipitated and the reducing effect of sulfur compounds has been overcome.

10. Apparatus

10.1 *Photometer*—Spectrophotometer or filter photometer suitable for use at 540 nm and equipped with a cell having a

minimum path length of 10 mm. The photometers and photometric practice prescribed in this test method shall conform to Practice E60. Spectrophotometers and spectrophotometric practice shall conform to Practice E275.

11. Reagents and Materials

11.1 *Chromium Solution, Stock* (1 mL = 0.10 mg Cr)—Dissolve 0.2828 g of potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) that has been oven dried at 105°C for 1 h in water. Dilute to 1 L with water. Alternatively, certified stock solutions are commercially available through chemical supply vendors and may be used.

11.2 *Chromium Solution, Standard* (1 mL = 0.001 mg Cr)—Dilute 10.0 mL of chromium stock solution (see 11.1) to 1 L with water.

11.3 *Diphenylcarbazide Indicator Solution*—Dissolve 0.25 g of powdered 1,5-diphenylcarbohydrazide in 100 mL of acetone. Store in an amber glass-stoppered flask at 4°C when not in use. This solution is stable for about one week when kept refrigerated. Prepare fresh reagent when the solution becomes discolored.

NOTE 3—Allow the indicator solution to warm to room temperature before use.

11.4 *Phosphoric Acid* (1 + 1)—Dilute 500 mL of concentrated phosphoric acid (sp gr 1.69) to 1 L with water.

11.5 *Phosphoric Acid* (1 + 19)—Dilute 50 mL of concentrated phosphoric acid (sp gr 1.69) to 1 L with water.

11.6 *Sodium Hydroxide Solution* (40 mg/L)—Dissolve 40 mg of sodium hydroxide (NaOH) in water. Cool and dilute to 1 L. This solution is used for sample preservation.

11.7 *Sulfamic Acid* ($\text{NH}_2\text{SO}_3\text{H}$)—Crystals.

11.8 *Filter Paper*—Purchase suitable filter paper. Typically the filter papers have a pore size of 0.45- μm membrane. Material such as fine-textured, acid-washed, ashless paper, or glass fiber paper are acceptable. The user must first ascertain that the filter paper is of sufficient purity to use without adversely affecting the bias and precision of the test method.

12. Calibration

12.1 Prepare a series of at least four standard solutions containing from 0 to 0.50 mg/L of chromium by diluting measured volumes of the standard chromium solution (see 11.2) to 100 mL with water in separate volumetric flasks.

12.2 Transfer 50 mL of each prepared standard solution to separate 125-mL Erlenmeyer flasks and proceed with 13.3 – 13.6.

12.3 Prepare a calibration curve by plotting milligrams per liter of chromium versus absorbance on linear graph paper.

12.4 Read directly in concentration if this capability is provided with the instrument or prepare a calibration curve for each photometer. A recalibration must be made if any alterations of the instrument are made or if new reagents are prepared. At the least, a blank and three chromium standard solutions must be analyzed to verify the original test calibration each time the test is performed.

TABLE 1 Determination of Bias and Precision, Photometric Diphenylcarbohydrazide

	Amount Added, mg/L	Mean Recovery (X), mg/L	± Bias	± % Bias	Statistically Significant at 5 % Level	S _T	S ₀
Reagent water:	0.010	0.0125	+0.0025	+25.0	yes	0.006	0.0031
	0.050	0.0502	+0.0002	+0.40	no	0.007	0.0053
	0.350	0.3484	-0.0016	-0.46	no	0.022	0.0130
	0.500	0.4964	-0.0036	-0.72	no	0.022	0.0139
Water of choice:	0.010	0.0112	+0.0012	+12.0	no	0.005	0.0025
	0.050	0.0468	-0.0032	-6.40	yes	0.007	0.0042
	0.350	0.3378	-0.0122	-3.49	yes	0.026	0.0159
	0.500	0.4776	-0.0224	-4.48	yes	0.038	0.0204
Leachate:	0.010	0.0148	+0.0048	+48.0	yes	0.008	0.0037
	0.050	0.0513	+0.0013	+2.60	no	0.009	0.0062
	0.350	0.3422	-0.0078	-2.23	yes	0.015	0.0093
	0.500	0.4887	-0.0113	-2.26	yes	0.025	0.0130

13. Procedure

13.1 Filter a portion of the sample through a 0.45-μm membrane filter (11.8) and adjust the pH into the 8 to 8.5 range if it is greater than 8.5 with a few drops of the phosphoric acid solution (1 + 19).

13.2 Transfer 50.0 mL of the filtered sample, or a smaller aliquot of sample diluted to 50.0 mL, to a 125-mL Erlenmeyer flask.

13.3 Add 2.0 mL of the diphenylcarbazide solution to each solution and swirl to mix.

NOTE 4—If the sample is colored, prepare a separate aliquot as described in 13.1 and 13.2. Add 2.0 mL of acetone instead of diphenylcarbazide solution and proceed with 13.4 and 13.5. Use this solution as the sample blank.

13.4 Immediately add 5.0 mL of phosphoric acid solution (1 + 1) to each solution and swirl to mix.

13.5 Permit the solutions to stand 15 min for full color development. Measure the absorbance within 30 min after the addition of the diphenylcarbazide solution at 540 nm with a cell having a minimum path length of 10 mm.

13.6 Determine milligrams per liter of chromium as Cr⁺⁶ in the test sample by referring the direct instrument reading or the absorbance to the prepared calibration curve (see 12.3).

14. Calculation

14.1 Calculate the hexavalent chromium concentration as follows:

$$Cr^{+6}, \text{ mg/L} = (W_S - W_B)(50/S) \quad (1)$$

where:

- W_S = chromium found in the sample, mg/L (see 13.6),
W_B = chromium found in the sample blank, mg/L (see 13.6),
and
S = volume of sample used, mL (see 13.2).

15. Precision and Bias

15.1 The collaborative test data were obtained on reagent grade water Types I, II, and III, tap water, 10 % NaCl solution, treated water from a synthetic organic industrial plant which meets NPDES permit requirements, EPA-extraction procedure

leachate water, process water, lake water, effluent from treatment, that is, lime neutralization and precipitation of spent pickle liquor and associated rinse water from stainless steel pickling.

15.2 Single-operator and overall precision of this test method within its designated range and recovery data for the above waters for 16 laboratories, which include a total of 16 operators analyzing each sample on three different days, is given in Table 1.

15.3 Single-operator and overall precision of this test method within its designated range and recovery data for a prepared leachate water for 8 laboratories, which include a total of 8 operators analyzing each sample on three different days, is also given in Table 1.

15.4 It is the user's responsibility to ensure the validity of the test method for waters of untested matrices.

15.5 Precision and bias for this test method conforms to Practice D2777-77, which was in place at the time of collaborative testing. Under the allowances made in 1.4 of Practice D2777-13, these precision and bias data do meet existing requirements for interlaboratory studies of Committee D19 test methods.

TEST METHOD B—ATOMIC ABSORPTION, DIRECT

16. Scope

16.1 This test method covers the determination of dissolved and total recoverable chromium in most waters, wastewaters, and brines.

16.2 The test method is applicable in the range from 0.1 to 10 mg/L of chromium. The range may be extended to concentrations greater than 10 mg/L by dilution of the sample.

16.3 It is the user's responsibility to ensure the validity of this test method for waters of untested matrices.

17. Summary of Test Method

17.1 Chromium is determined by atomic absorption spectrophotometry. Dissolved chromium is determined by aspirating a portion of the filtered sample directly with no pretreatment. Total recoverable chromium is determined by aspirating

the sample following hydrochloric-nitric acid digestion and filtration. The same digestion procedure is used to determine total recoverable cadmium (Test Methods [D3557](#)), nickel (Test Methods [D1886](#)), cobalt (Test Methods [D3558](#)), copper (Test Methods [D1688](#)), iron (Test Methods [D1068](#)), lead (Test Methods [D3559](#)), manganese (Test Methods [D858](#)) and zinc (Test Methods [D1691](#)).

18. Interferences

18.1 Iron, nickel, and cobalt at 100 µg/L and magnesium at 30 mg/L interfere by depressing the absorption of chromium. These interferences are eliminated in solutions containing 10,000 mg/L of 8-hydroxyquinoline. Samples adjusted to this concentration show no interference from 700 mg/L of iron and 10 mg/L each of nickel and cobalt, or from 1000 mg/L of magnesium.

18.2 Potassium above 500 mg/L enhances the chromium absorption.

18.3 Sodium, sulfate, and chloride (9000 mg/L each), calcium and magnesium (4000 mg/L each), nitrate (2000 mg/L), and cadmium, lead, copper, and zinc, (10 mg/L each) do not interfere.

19. Apparatus and Materials

19.1 *Atomic Absorption Spectrophotometer*, for use at 357.9 nm. A general guide for the use of flame atomic absorption applications is given in Practice [D4691](#).

NOTE 5—The manufacturer's instructions should be followed for all instrumental parameters. Wavelengths other than 357.9 nm may be used if they have been determined to be equally suitable.

19.1.1 *Chromium Hollow Cathode Lamp*, multielement hollow-cathode lamps.

19.2 *Oxidant*—See [20.7](#).

19.3 *Fuel*—See [20.8](#).

19.4 *Pressure-Reducing Valves*—The supplies of fuel and oxidant shall be maintained at pressures somewhat higher than the controlled operating pressure of the instrument by suitable valves.

20. Reagents and Materials

20.1 *Chromium Solution, Stock* (1 mL = 1.0 mg Cr)—Dissolve 2.828 g of primary standard potassium dichromate ($K_2Cr_2O_7$) in 200 mL of water and dilute to 1 L. Alternatively, certified stock solutions are commercially available through chemical supply vendors and may be used.

20.2 *Chromium Solution, Standard* (1 mL = 0.1 mg Cr)—Dilute 100.0 mL of the chromium stock solution and 1 mL of HNO_3 (sp gr 1.42) to 1 L with water.

20.3 *Hydrochloric Acid* (sp gr 1.19)—Concentrated hydrochloric acid (HCl).

NOTE 6—If a high reagent blank is obtained, distill the HCl or use a spectrograde acid.

(**Warning**—When HCl is distilled an azeotropic mixture is obtained (approximately 6 N HCl). Therefore, whenever con-

centrated HCl is specified for the preparation of a reagent or in the procedure, use double the amount specified if a distilled acid is used.)

20.4 *8-Hydroxyquinoline Solution* (100 g/L)—Dissolve 50 g of 8-hydroxyquinoline in 35 mL of HCl (sp gr 1.19). Warm the mixture gently on a hot plate to facilitate dissolution. Transfer to a 500-mL volumetric flask and bring to volume with the careful addition of water. Use a hood.

20.5 *Nitric Acid* (sp gr 1.42)—Concentrated nitric acid (HNO_3).

NOTE 7—If a high reagent blank is obtained, distill the HNO_3 or use a spectrograde acid.

20.6 *Nitric Acid* (1 + 499)—Add 1 volume of HNO_3 (sp gr 1.42) to 499 volumes of water.

20.7 *Oxidant*:

20.7.1 *Air* that has been passed through a suitable filter to remove oil, water, and other foreign substances, is the usual oxidant.

20.7.2 *Nitrous Oxide*, medical grade, is satisfactory.

20.8 *Fuel*:

20.8.1 *Acetylene*—Standard, commercially available acetylene is the usual fuel. Acetone, always present in acetylene cylinders, can affect analytical results. The cylinder should be replaced at 345 kPa (50 psi). (**Warning**—“Purified” grade acetylene containing a special proprietary solvent rather than acetone should not be used with poly(vinyl chloride) tubing as weakening of the tubing walls can cause a hazardous situation.)

20.9 *Filter Paper*—See [11.8](#).

21. Standardization

21.1 Prepare 100 mL each of a blank and at least four standard solutions, containing 1 mL of 8-hydroxyquinoline solution (100 g/L)/10 mL of standard, to bracket the expected chromium concentration range of the samples to be analyzed, by diluting the standard chromium solution (see [20.2](#)) with HNO_3 (1 + 499). Prepare the standards each time the test is to be performed.

21.2 To determine the total recoverable chromium, add 0.5 mL of HNO_3 (sp gr 1.42) and proceed as directed in [22.3 – 22.5](#). To determine dissolved chromium, proceed with [21.3](#).

21.3 Aspirate the blank and standards and record the absorbance or concentration at 357.9 nm. Aspirate HNO_3 (1 + 499) between each standard.

21.4 Read directly in concentration if this capability is provided with the instrument or prepare an analytical curve by plotting the absorbance versus concentration for each standard on linear graph paper.

22. Procedure

22.1 Clean all glassware to be used for preparation of standard solutions or in the digestion step, or both, by soaking the glassware overnight in HNO_3 (1 + 1) and then rinsing with reagent.

22.2 Measure 100.0 mL of a well-mixed acidified sample into a 125-mL beaker or flask.

NOTE 8—If only dissolved chromium is to be determined, start with 22.6.

22.3 Add 5 mL of HCl (sp gr 1.19) to each sample.

22.4 Heat the samples (between 65°C to 95°C) on a steam bath or hotplate below boiling in a well-ventilated hood until the volume has been reduced to 15 to 20 mL, making certain that the samples do not boil.

NOTE 9—When analyzing brines and samples containing appreciable amounts of suspended matter or dissolved solids, the amount of reduction in the volume is left to the discretion of the analyst.

NOTE 10—Many laboratories have found block digestion systems a useful way to digest samples for trace metals analysis. Systems typically consist of either a metal or graphite block with wells to hold digestion tubes. The block temperature controller must be able to maintain uniformity of temperature across all positions of the block. The digestion block must be capable of maintaining a temperature between 65°C to 95°C. For trace metals analysis, the digestion tubes should be constructed of polypropylene and have a volume accuracy of at least 0.5 %. All lots of tubes should come with a certificate of analysis to demonstrate suitability for their intended purpose.

22.5 Cool and filter the samples through a suitable filter such as fine-textured, acid-washed, ashless paper, into 100-mL volumetric flasks. Wash the filter paper two to three times with water and bring to volume.

22.6 Pipette 10.0 mL of sample into a 50-mL beaker and add 1.0 mL of 8-hydroxyquinoline solution.

22.7 Aspirate each filtered and acidified sample and determine its absorbance or concentration. Aspirate HNO₃ (1 + 499) between each sample.

23. Calculation

23.1 Read directly in concentration or calculate the concentration of chromium in the sample, in milligrams per liter, using the analytical curve prepared in 21.4.

24. Precision and Bias⁴

24.1 The overall precision (S_T) of this test method within its designated range for six laboratories, which include a total of nine operators analyzing each sample on three different days, varies linearly with the chromium concentration, X , in milligrams per liter.

24.1.1 For reagent water:

$$S_T = 0.097X + 0.010 \quad (2)$$

24.1.2 For selected water matrices:

$$S_T = 0.079X + 0.019 \quad (3)$$

where:

S_T = overall precision, mg/L, and

X = concentration of chromium, mg/L.

24.2 Single-operator precision did not differ significantly from overall precision.

24.3 Recoveries of known amounts of chromium from reagent water and selected water matrices are given in Table 2.

TABLE 2 Determination of Bias, Atomic Absorption, Direct

	Amount Added, mg/L	Amount Found, mg/L	Bias	Bias, %	Statistically Significant (95 % confidence level)
Reagent water:					
	0.4	0.399	-0.001	-0.25	no
	3.0	2.89	-0.11	-3.7	no
	7.0	6.99	-0.01	-0.14	no
Selected water matrices:					
	0.4	0.425	+0.025	+6.2	yes
	3.0	3.095	+0.095	+3.2	no
	7.0	7.180	+0.180	+2.6	no

24.4 The selected waters used in this study are not available. It is the user's responsibility to ensure the validity of the test method for waters of untested matrices.

24.5 Precision and bias for this test method conforms to Practice D2777 – 77, which was in place at the time of collaborative testing. Under the allowances made in 1.4 of Practice D2777 – 13, these precision and bias data do meet existing requirements for interlaboratory studies of Committee D19 test methods.

TEST METHOD C—ATOMIC ABSORPTION, GRAPHITE FURNACE

25. Scope

25.1 This test method covers the determination of dissolved and total recoverable chromium in most waters and wastewaters.

25.2 This test method is applicable in the range from 5 to 100 µg/L of chromium (Refer to Practice D3919, Footnote in Table 1) based on a 20-µL sample size. The range can be increased or decreased by varying the volume of sample injected or the instrumental settings. High concentrations may be diluted but preferably should be analyzed by direct aspiration atomic absorption spectrophotometry.

25.3 This test method has been used successfully with reagent water, stack scrubber water, lake water, filtered tap water, river water, condensate from medium BTU coal gasification process, well water, and production plant water. It is the user's responsibility to ensure the validity of the test method for waters of untested matrices.

26. Summary of Test Method

26.1 Chromium is determined by an atomic absorption spectrophotometer used in conjunction with a graphite furnace. A sample is placed in a graphite tube, evaporated to dryness, charred (pyrolyzed or ashed), and atomized. Since the graphite furnace uses the sample much more efficiently than flame atomization, the detection of low concentrations of elements in small sample volumes is possible. Finally, the absorption signal during atomization is recorded and compared to standards. A general guide for the application of the graphite furnace is given in Practice D3919.

26.2 Dissolved chromium is determined on a filtered sample with no pretreatment.

⁴ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D19-1036. Contact ASTM Customer Service at service@astm.org.